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VOLUME I

PAPERS PRESENTED

STATE COUPLED RESOURCE ASSESSMENT PROGRAM

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PROGRAM ACCOMPLISHMENTS AND FUTURE PROSPECTS FOR LOW-TEMPERATURE GEOTHERMAL RESOURCE ASSESSMENT IN NEW MEXICO

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1.0 Introduction

The New Mexico State University Energy Institute (NMSUEI) is in its fourth, and apparently last, year of low-temperature geothermal resource exploration and assessment supported by the Department of Energy State-Coupled Low Temperature Geothermal Resource Assessment Program. This broadly based research, performed principally by faculty and staff at the University of New Mexico, the New Mexico Institute of Mining and Technology, and New Mexico State University and managed by the Institute, has revealed numerous areas in New Mexico that may contain commercially exploitable low-temperature geothermal resources. At present, the knowledge about each area varies; some areas require additional reconnaissance-level investigations, and others warrant detailed local surveys, including temperature gradient drilling for reservoir confirmation. An important component of this program has been basic studies in specific regions of New Mexico, including areas adjacent to the cities of Albuquerque, Las Cruces, Socorro, and Truth or Consequences. Considerable geological, hydrological, electrical resistivity, gravity, magnetic, seismic, water analysis, and subsurface temperature data have been compiled and analyzed by university researchers for these locations.

2.0 Specific State-Coupled Program Accomplishments

During the four-year research program, a total of 25 tasks have been undertaken. Eleven of these tasks were focused toward collecting and compiling statewide data, six were regional studies covering more than one county, and eight were research projects directed primarily toward data collection near specific cities or known resource areas. Two of these latter studies contributed significantly to the confirmation of the Las Alturas geothermal anomaly east of Las Cruces. The following three subsections give a brief summary of the program accomplishments by task.

2.1 Statewide Studies and Results

1. Compilation of spring and well temperatures in excess of 20°C

   - Nearly all groundwaters in southern New Mexico have temperatures in excess of 20°C
   - Numerous geothermal prospects in western New Mexico contain high-quality, high-temperature waters suitable for direct use applications
   - At least 7 and perhaps as many as 20 areas may have subsurface temperatures in excess of 150°C, which is suitable for electricity production

2. Analysis and mapping of existing deep oil, gas, and water well data

   - Bottom-hole temperatures in deep wells in seven New Mexico counties compiled and mapped
   - 46 anomalous low temperature geothermal areas in New Mexico identified

3. Collection of oil and gas well data

   - 15,732 data points collected throughout New Mexico, most wells in Rio Arriba (4,625) and San Juan (7,850) counties
   - Average San Juan Basin oil and gas well temperature gradient is 26.9°C/km
   - Bottom-hole temperature depth plot completed for northwestern counties
   - 149 wells identified with temperature gradients of 40°C/km or higher

4. Tabulation of water quality information

- Most thermal waters in New Mexico have salinities in the range of 1,000 to 3,000 ppm TDS
- Several areas in the Gila National Forest and near Socorro have salinities below 400 ppm TDS
- Only known thermal area in New Mexico associated with high levels of objectionable chemical constituents is the Valles Caldera region

5. Compilation of heat flow data

- Zone of high heat flow (> 2.5 HFU) trends north to south through central New Mexico and is associated with the Rio Grande Rift
- Heat flow values in the Basin and Range fall between 2 and 3 HFU
- Colorado Plateau and eastern New Mexico have nearly normal heat flow values of about 1.5 HFU

6. Collection of seismicity data

- 53 earthquakes with modified Mercalli of 5 or greater reported prior to 1961, approximately 67% located in the Rio Grande Rift
- 224 earthquakes recorded during the period 1961 through 1977 with local magnitudes greater than 1.5
- 23 earthquakes with local magnitudes (M_L > 1.5) occurred from 1978 through 1980, principally within the Rio Grande Rift
- Highest amount of activity was in the central part of the rift near Socorro

7. Collection and mapping of Quaternary volcanism and tectonism information

- Locations of Quaternary and late Pliocene tectonic activity and volcanism mapped
- Quaternary and late Pliocene age dates, mining prospects, and water isotope analyses mapped

8. Construction of a lineament map of New Mexico

- Fault system is dominated by NW and NE orthogonal set of faults
- N-S faults are restricted to the Rio Grande Rift, west, and southwest New Mexico
- Basin and Range is dominated by NW faults
- Most known geothermal areas lie at intersections of the Rio Grande Rift and NW-SE transform zones

9. Compilation of data resulting from geoelectric investigations supplemented with field study data

- Index map for geoelectrical studies in New Mexico
- 147 geoelectrical study references compiled

10. Completion of the public and scientific geothermal resources maps (scale, 1:500,000)

- ° Public geothermal resources map published in 1980
- ° Draft of scientific geothermal resources map under review
- ° Most of the data sets for scientific map insets and overlays completed

11. Preparation of an aeromagnetic map (in progress)

- ° Compatible with state geologic and Bouguer gravity maps (scale, 1:500,000)
- ° Digital data grid will be available on magnetic tape

2.2 Regional Studies and Results

1. Updated temperature data from existing water wells in southwestern New Mexico

- ° 98 water wells identified, 13 suitable for temperature logging
- ° Most boreholes were shallow (< 25 m) and cold
- ° 3 wells identified as anomalous, two in known areas of geothermal promise

2. Interpretation of geological, geophysical, and hydrologic data to assess geothermal energy potential in Catron, Dona Ana, Grant, Hidalgo, Luna, and Sierra counties

- ° Hydrothermal systems associated with late Quaternary faulting
- ° Known geothermal areas coincide with intersections of NW-SE and N-S trends of structural weakness
- ° Maps (scale, 1:250,000) of tectonic features, gravity, temperature data geothermal anomalies completed
- ° 4 temperature gradient holes drilled with above normal heat flow values of 2.5 to 3.5

3. Fault mapping and age dating in the Columbus, Black Range, Potrillo Mountain, and southern Tularosa Basin areas

- ° Locations of all known faults in south central New Mexico which have been active during the last 0.4 million years mapped
- ° 15 basaltic volcanic rocks determined by radiometric dating
- ° 14 basaltic volcanic rocks classified by chemical analyses and mineralogical studies

4. Electrical resistivity studies in Dona Ana and Luna counties

- ° Schlumberger depth soundings along three Schlumberger profiles completed
- ° Faults interpreted from resistivity profiles plotted for the Las Cruces area

5. Interpretation of geological and geophysical data to assess geothermal energy potential in Bernalillo, Los Alamos, Mora, Rio Arriba, San Miguel, Sandoval, Santa Fe, Taos, Torrance, and Valencia counties (in progress)

6. Geothermal exploration in Otero and Lincoln counties (in progress)

2.3 Area-Based Studies and Results

1. Seismic, water analyses, and hydrology studies in the Socorro area

   - Tritium activity, major chemical constituents, deuterium, and oxygen-18 concentrations determined in selected samples of springs, wells, groundwaters, and precipitation
   - Depth to the aquitard in the Upper Popotosa Formation determined (at depths greater than 2,200 m) by active seismic reflection techniques

2. Mapping of hot springs and faults, gravity and aquifer studies, and temperature logging of existing wells in the Truth or Consequences area

   - Geological mapping of the Mud Springs Mountains area
   - Thermal and nonthermal aquifers identified and described by geological mapping, field observations, aerial photography, and direct measurements
   - Discharge area geology and age of fault controlled springs described
   - 6 water wells temperature logged

3. Magnetic and electrical resistivity surveys and drilling temperature gradient holes on the Albuquerque west mesa

   - Ground magnetic surveys (175 km^2) completed
   - Two dipole-dipole lines (5 and 8 km) completed
   - 5 deep (280 to 440 m) water wells logged
   - Highest measured temperature gradient in over 100 holes is 120°C/km

4. Computer-based hydrologic study of the Animas Valley/Lightning Dock KGRA area

   - Hydrogeologic data collected, reviewed, and analyzed statistically
   - Flow net analysis performed
   - Calibrated two-dimensional computer model developed to predict drawdown, water level, and hydraulic head
   - Maps of groundwater temperature, salinity, and chloride, sulfate, sodium, and lithium concentrations prepared

5. Temperature and heat flow investigations in Dona Ana County

   - 62 abandoned water wells and shallow temperature gradient holes temperature logged
   - Conductive heat flow values about the water table have a modal class of 2.4 to 3.6 HFU and a range exceeding -1 to 16 HFU
   - Cool groundwater recharge and lateral groundwater flow and upward convecting hot water are believed to be the cause of the anomalously low and high heat flow values, respectively
   - Geological, geophysical, and hydrologic data suggest the existence of a fault-controlled hydrothermal system

6. Electrical resistivity studies in the Chamberino and Mesquite areas

   - Zone of low resistivity (10 km long by 5 km wide) identified by Schlumberger soundings and profiles
   - Electrical resistivity data suggest complex faulting and upwelling of geothermal fluids along faults

7. Seismic profiles of the Las Alturas geothermal reservoir

   - Gravity, magnetic, seismic-refraction, and seismic-reflection data sets collected and compared
   - Seismic reflection data indicate that there is no major faulting above 1,000 ft
   - Rise of geothermal waters near test holes is predicted to be pore-or microfracture-controlled, rather than major fracture-controlled, flow

8. Drilling of two 1,000-foot exploratory geothermal wells

   - 8 water wells in the Las Alturas area temperature logged
   - 6 30-m temperature gradient wells drilled
   - 300-m and 360-m slim gradient holes drilled with bottom-hole temperatures of 145°F and 123°F, respectively.

2.4 Geothermal Maps of New Mexico

During 1980, a major step toward the initial goals of the low-temperature geothermal resource assessment program was taken when the Geothermal Resources of New Mexico map was published. This map, designed for use by the general public, entrepreneurs, and regional planners, shows data on thermal springs and wells (e.g., temperatures, flow rates, salinities, and depths), heat-flow

values, delineated low-temperature resource areas, and descriptions of present or projected geothermal energy users. Land status, including Known Geothermal Resource Areas, and topographic data are also displayed on this map.

A scientific geothermal resources map, showing basic geological, geochemical, and geophysical data, will be published following the completion of the program in 1982. This map, the first and, perhaps, only state scientific geothermal map to be printed by the National Oceanic and Atmospheric Administration, will be accompanied by a compilation of associated technical references so that interested individuals may access all relevant data for any specific site. The base map will display Quaternary volcanic and tectonic features, Quaternary igneous age dates, and abnormally high oil and gas well bottom-hole temperatures. Earthquake epicenters, heat-flow contours, and seismic data will be shown as insets. Five overlays (hydrology, geochemical, lineament, Bouguer gravity, and magnetic data) will be included as part of the map series. Deep sedimentary basins, groundwater constrictions, and temperature gradient contours will be shown on the hydrology overlay. The geochemical overlay will contain geochemical anomalies, stiff diagrams (groundwater salinities) for geothermal waters, oxygen and hydrogen isotope data, and estimated temperatures by SiO_2 and Na-K-Ca geothermometers.

3.0 State of New Mexico Activities

During the period from 1974 through 1980, the State of New Mexico funded 47 geothermal energy research and development projects for a total expenditure of more than $2 million. These projects covered a wide range of activities from surface exploration, system feasibility studies, engineering design, commercialization programs, to test well drilling. Some of these projects

were direct New Mexico contributions to the federally-funded State-Coupled Low Temperature Geothermal Resource Assessment Program. Approximately $1.2 million have been committed to 26 projects that are either directly-linked or closely related to the goals of the State-Coupled Program, which has had cumulative expenditures of about $0.9 million. Much of the data collected by these state-funded research programs is summarized on the Geothermal Resources of New Mexico public map or will be included in the scientific map series.

4.0 Program Successes

The resource assessment programs in New Mexico have been very successful in (1) delineating low-temperature geothermal resources throughout New Mexico on statewide, regional, and area-specific scales; (2) developing a strong community of in-state geothermal energy research and development professionals and practitioners; and (3) elevating the level of awareness of geothermal energy potential among commerce, industry, and the general public. The ultimate measure of success of a resource assessment and exploration program must be the identification of commercially-viable geothermal resources. Reservoir confirmation, based on site-specific surface studies followed by test and production drilling, is a key and necesssary element in the development of commmercial applications of low-temperature geothermal energy resources. In New Mexico, experience indicates that neither private resource developers nor potential users will take the financial risks necessary to gain sufficient knowledge of low-temperature resources to make commercial developments a reality, without considerable expenditure of public funds to reduce the risks of drilling the first production well in any resource area.

An excellent example of the use of public monies to build this knowledge base is the geothermal heating project at the New Mexico State University

campus. Support from the State-Coupled Low Temperature Geothermal Resource Assessment Program allowed a resource with no surface manifestations to be identified, temperature gradient holes to be drilled, and the first production well to be completed, which permited additional State and Department of Energy funds to be obtained to perform a system design and complete a second production well. This work provided the necessary background information for use in acquiring additional funds from the State of New Mexico to construct a low-temperature ($\sim$140°F) geothermal energy system to heat domestic hot water for 11 campus buildings and an outdoor swimming pool. Dedication of the $1.2 million project is scheduled for late April 1982. This project, which will save New Mexico taxpayers in excess of $300,000 per year on natural gas purchases, would not have become a reality without the initial support from the State of New Mexico and the State-Coupled Low Temperature Geothermal Resource Assessment Program and is, perhaps, the star of the New Mexico Energy Research and Development Program.

5.0 Future Prospects

In a climate of reorientation from federally-supported activities, New Mexico's already established infrastructure and past state-funded programs focused toward research, development, and demonstration of low-temperature geothermal energy technologies are a strong advantage. The current activities at the New Mexico State University Energy Institute stand ready to provide the framework and expertise for the transition from federal government support of geothermal resource assessment to state- and/or privately-funded activities to build the resource knowledge base necessary for successful adoption of low-temperature geothermal energy technology by the private sector.

5.1 State of New Mexico Programs

In 1981, the New Mexico Energy Research and Development Program was reorganized into a quasi-independent agency known as the New Mexico Energy Research and Development Institute. This new agency plans to reduce the breadth of the previous program by concentrating research and development activities in four to six energy technology areas. The principal criterion for selection of technology areas and associated programs will be the potential for contributions to economic development in the short-term, measured simplistically as increases in state revenues and private-sector employment opportunities. A statewide debate is now in progress over the selection of the target energy areas. Preliminary discussions suggest that low-temperature geothermal energy will be included in the selected areas, in part, because of the success of and the public and private sector interests in the geothermal heating project at New Mexico State University.

On the other hand, there is substantial pressure to focus on the commercialization end of the research and development spectrum, which could serve to largely exclude the support of geothermal resource assessment and exploration activities. Since the new agency's charge is clearly economic development, carefully focused area- or site-specific exploration and reservoir confirmation programs that have a clear connection to the future adoption of geothermal energy by the private sector should be of interest to the state program. Annual commitments comparable to those of the past (i.e., $100,000 to $200,000) should be obtainable, if some early demonstrated successes in commercial development result from targeted resource assessment programs and areas of inquiry. Efforts to undertake large and costly resource assessment and exploration activities with long payoff schedules will certainly not be viewed favorably.

An additional source of support may be the state-funded geothermal demonstration program which has a $600,000 appropriation that must be committed prior to June 30, 1982, and requires a one-to-one financial match by the applicant. Site-specific reservoir confirmation studies qualify under this program, if a potential user can be identified. University-based participation in this program presents a special challenge because of the financial match requirements which, in practice, will require a cooperative arrangement with private sector institutions providing the matching funds.

5.2 Cooperative Programs with Industry

Establishment of cooperative resource assessment and exploration programs with industry is a difficult challenge to public university-based researchers. Many conflicts can arise over topics such as distributive share of financial commitments, project control, materiel and services purchasing practices, academic scheduling constraints, indirect cost contributions, privacy of data, and work locations. Recent experiences at New Mexico State University Energy Institute indicate that private support of university-based resource assessment projects will only occur if some arrangement is made for sharing the financial costs of the program. This requirement typically cannot be met unless state-funded programs are available.

During the past year, two separate cooperative agreements with private industry for resource assessment activities in Dona Ana County have been executed by the Energy Institute. In each of these projects, costs were shared using state research funds, the Institute had overall project control, state purchasing requirements were honored, academic scheduling problems were eliminated by using only full-time professional staff rather than faculty, indirect costs were absorbed by the university, data remained confidential for a negotiated period of time, and work locations were mutually agreed upon

consistent with private leaseholds and state exploration interests. In one case, there was a clearly defined plan for commercialization if the low-temperature geothermal resources were found to be adequate for development. Preliminary resource assessment was the primary objective in the second program. Differences in the project objectives were reflected in the detailed financial arrangements.

Two fundamental characteristics of industrial interests in resource assessment and exploration programs create troublesome situations for state-supported university-based activities performed by professional staff that are not amendable to negotiated solutions. The intermittent nature of industrial exploration efforts makes continuity in staffing impossible without a source of continuous support to maintain a highly-qualified core group of researchers. Secondly, site-specific interests of industry are often in conflict with the political realities of distributing state funds geographically. If innovative solutions to these two problems can be found, resource assessment activities in New Mexico, based on cooperative agreements with industry, could abound because of the recent increased commitment of private capital for exploratory and production well drilling in the southern part of the state.

6.0 Concluding Remarks

Low-temperature geothermal resource assessment programs will be extremely difficult, if not impossible, to maintain in most states without federal support. A few states may be able to support a low-level program through existing organizations such as a bureau of mines or university-based research institutes. Although the low-temperature geothermal resource assessment activities in New Mexico will be reduced in scope following the withdrawal of

federal support, New Mexico is almost certain to have one of the most active programs among the western states. If the first privately-financed successful low-temperature geothermal resource development occurs within the next twelve months, can be shown conclusively to have benefited substantially from publicly-supported resource assessment activities, and triggers rapid deployment of geothermal energy technologies, all of which are not that unlikely, the future prospects for resource assessment programs in New Mexico should be exciting.